Communication Systems

Digital source: finite or countable set of messages

Analog source: produces messages that vary in a continuum way

A digital communication system transmits and receives messages from a digital source.

An analog communication system transmits and receives messages from an analog source.
Example communication systems

- Prehistoric: animal comm.; analog
- 4-5K years ago: written language; digital
- 1834: Gauss-Weber telegraph; digital
- 1876: Bell telephone; analog
- 1894: wireless radio; analog
- 1918: Armstrong superheterodyne receiver; analog
- 1920: Carson applies sampling in communications
- 1926: Baird-Jenkins television; analog
Example communication systems

• 1933: Armstrong invents FM; analog
• 1935: Watson-Watt radar; analog
• 1947: Bell Lab invents transistors
• 1948: Shannon published information theory
• 1958: Kilby-Noyce built integrated circuits
• 1963: Bell touch-tone phone; digital
• 1972: Motorola cellular phone; analog
• 1980: Bell fiber-optic communication; analog
• 1989: GPS
• 1990’s: Internet and the digital comm era
Where things are and where they are heading

Today’s office

Future office

10/100/1000 Ethernet

802.11x

USB Hub

USB 2.0

Monitor 2-4Gbps

Office (opt)

Office (core)
Layered Geolocation Networks
Smart Home Networks
Small Unit Operations Environment for Situation Awareness Systems (SUO-SAS)
Non-Homogeneous Wireless Networks
A. Input acquired from OSCILLATOR (1000 KHZ)

B. A 2nd signal from transducer is mixed with 1000 CW to produce an Amplitude Modulated (AM) signal or Carrier Transmission.

Now Back to old, existing

AM Radio
Video part

Oscillator and PLL

A lot of filtering

Quadrature modulation
TV receiver
Optical Transceiver Architecture

Optical Fiber → Photodetector → TIA → Postamp → Clock And Data Recovery

Laser Diode → LDD

Output: Clk out, Data out

Input: Data in

BERT

PRBS

Optical Channel
OE Devices
Transceiver
Test
AGC Postamplifier

- Automatic gain control maintains gain stages in their linear region to reduce jitter
- Excess gain can be dynamically traded for additional bandwidth and better phase response
- Different gain control for each VGA stage to reduce noise
Laser Diode Driver

- Cherry-Hooper limiting preamplifier
- Transconductance amplifier output stage
Interleaved PRBS Architecture

• The shift register operates at only half the data rate
Generic Wireless Phone Block Diagram

- Transmit and Receive RF
  - Tx / Rx Switch
  - Rx Amp / Filter
  - Power Amp
  - PA
  - Buffer
  - PA Control
  - Power Mgmt/Audio/Control
  - Logic Vcc
  - Tx Vcc
  - Rx Vcc
  - Regulator

- IF / Frequency Generation
  - Synthesizer
  - A/D
  - D/A

- Baseband Signal Processing
  - Digital Logic and Audio Processing
  - Audio CODEC
  - Memory
  - Display Driver
  - Keys/Buttons
  - Mic
  - Earpiece
  - PA Control
  - Audio Amp
  - EL Driver
  - Logic Vcc
  - TX Vcc
  - RX Vcc
  - Regulator

- Power Mgmt/Audio/Control
  - Logic Vcc
  - TX Vcc
  - RX Vcc
  - Regulator

- Digital Logic and Audio Processing
  - DSP / Micro-processor
  - Memory
  - Display Driver
  - Keys/Buttons
  - Mic
  - Earpiece
State-of-the-Art 2.5G Phone Architecture
State-of-the-Art 3G Smart Phone Architecture
Superheterodyne Receiver

+ Best overall performance
+ Usually lowest power
+ Flexible frequency plan
+ Avoid DC problems

- Expensive, large
- many discrete, external components
- Image problem
- Difficult for multi-mode (need multiple IF filters)
Direct Conversion Receiver

+ Eliminate IF SAW, IF PLL and image filtering
+ Integration
+ Avoids image problem

- Quadrature RF down conversion required
- DC problem
- Typically requires offset or 2x LO to avoid coupling

1/f noise here can end up in channel
Low IF receiver

+ Eliminate IF SAW, IF PLL and image filtering
+ Integration
+ Relaxes image rejection requirements
+ avoids DC problems

- Quadrature RF down conversion required
- Require higher performance ADC
- Additional mixer
  Slower RF PLL settling

+ Integration
+ Relaxes image rejection requirements
+ avoids DC problems
CMOS transceiver architecture
Our Focus is on VLSI Circuit Design

Cell phone example

Application in other communication systems

Analog and mixed-signal technology

Audio interface → Baseband conversion → RF

Antenna
Major components

- Antenna and interface
- RF input filter
- Low noise amplifier
- Mixer
- Oscillator
- Phase-locked loop
- Frequency synthesizer
- ADC/DAC
- Power amplifier
Performance Concerns

• DC offset
• Image rejection
• Quadrature requirements
• Noise and noise figure
• Phase noise and Jitter
• Distortion
  – Compression
  – Desensitization
  – Cross modulation
  – Intermodulation
  – IP2, IP3
  – Harmonic distortion (THD, SFDR, …)
• Bit error rate
• Data rate (bandwidth)